Pinus caribaea Morelet — Caribbean pine

Pinaceae — Pine family

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Pinus caribaea Morelet, commonly known as Caribbean pine, is the only tropical pine that grows naturally at low elevations. It is a tall, stately tree (fig. 1) that grows rapidly and produces a resinous wood useful for lumber and paper products. Caribbean pine is widely cultivated in plantations throughout the humid Tropics.

HABITAT

Native Range

The native range of Caribbean pine is a series of mostly isolated populations *(50)* (fig. 2). The northernmost populations are in the Bahamian area (to 27° N. latitude)—Grand Bahama, Great Abaco, New Providence, and Andros as well as three small islands in the Caicos group. Other populations are in the mountains of western Cuba and on the Isle of Pines (Cuba). The remaining populations are in Nicaragua, Honduras, and Belize, with small isolated populations in Guatemala and Quintana Roo, Mexico *(75)*. The range extends south to 12° N. latitude in Nicaragua.

Commercial plantations and adaptability tests of Caribbean pine have been established in most of the moist tropical countries. In Puerto Rico, the species reseeds itself near planted trees where there is disturbed soil or minimal vegetative competition *(31)*.

Climate

Caribbean pine grows in the Bahamas with as little as 750 mm of precipitation per year and in the upper Choluteca Valley of Honduras with about 600 mm of precipitation per year. On the other hand, areas of Caribbean pine range in Nicaragua receive as much as 4000 mm of rain annually *(10, 37)*. In the Bahamas and Cuba, Caribbean pine sites have a winter dry season (December through April) during which there is little rainfall. In the coastal lowlands of the Central American range, no month has less than 75 mm of precipitation, although conditions in April become dry enough for grass fires to occur. Inland areas of Central America have about 4 months with less than 75 mm of rainfall per month *(50)*. However, for acceptable growth of Caribbean pine in Central America, it is important that the dry season not exceed a duration of 4 months *(76)*.

The mean annual temperature of the Bahamian range is 25 °C. In the Cuban range, mean annual temperature ranges from 24.5 to 25.5 °C and in Central America from 20.0 to 27.0 °C *(10)*. The entire range is frost-free. In Central America, the species grows in the following life zones (sensu Holdridge *45)*: tropical dry forest, tropical moist forest, premontane moist forest, and premontane wet forest *(11)*. In the Caribbean, native stands are confined almost entirely to the subtropical moist forest life zone.

Soils and Topography

Within acceptable limits of climate, Caribbean pine is remarkably insensitive to soil conditions. Although this species grows best on fertile soil, it can grow well on nutrient-depleted and eroded lands such as old fields. In the Bahamas and the Caicos Islands, trees of the species grow on mildly alkaline to moderately alkaline (pH 7.5 to 8.5) soils *(10)*. In Cuba and Central America, Caribbean pine grows on very strongly acid to slightly acid (pH 4.5 to 6.5) soils. Trees from the Central American sources grow poorly or die on soils having a pH above 7.0. Caribbean pine can grow fairly well on soils that have saturated subsoils for part of the year but will not thrive on boggy sites.

Within Puerto Rican Caribbean pine plantations, soil type (Inceptisols, Ultisols, and Oxisols) evidently has no statistically significant effect on yield *(72)*. However, in the deep sands of the savannas in eastern Venezuela that receive 1000 mm/yr of precipitation (>120 cm deep before an increase in clay content is reached) and in soils with a perched water table during the wet season, Caribbean pine dies or grows very poorly *(32)*.

Figure 1.—*Twenty-five-year-old Caribbean pine* (Pinus caribaea) *plantation in Puerto Rico.*

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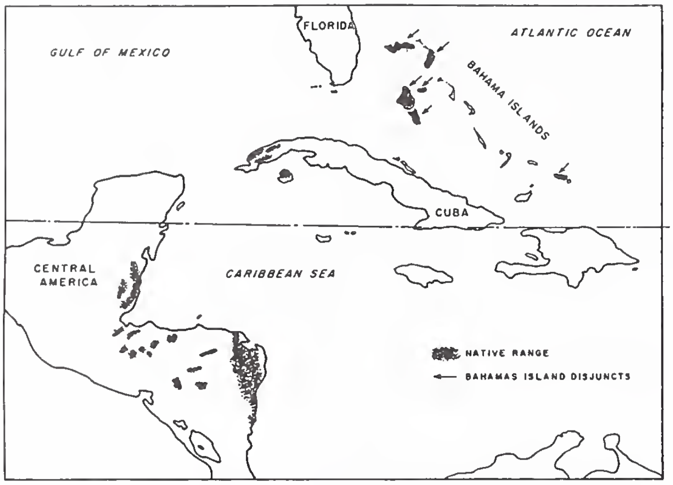

Figure 2.—*Native range of Caribbean pine* (Pinus caribaea) *in the West Indies, eastern central America, and southern Mexico.*

Caribbean pine grows naturally from near sea level to an elevation of 700 m, occasionally as high as 1000 m in Central America *(10, 75)*. Most native sites have gentle topography, but steep slopes present no particular difficulty for the species.

Associated Forest Cover

The Caribbean pine-dominated sites in the Bahamas also support the palms *Sabal palmetto* (Walt.) Lodd. ex J.A. & J.H. Schult., *Coccothrinax argentata* (Jacq.) Bailey, and *Thrinax* spp. and the dicots *Duranta repens* L., *Metopium toxiferum* (L.) Krug. et Urb., *Tetrazygia bicolor* (Mill.) Cogn., *Cordia bahamensis* Urban, *Ascyrum linifolium* Spach., *Randia aculeata* L., and *Turnera ulmifolia* L. *(42)*. Caribbean pine generally grows in pure stands on deep Oxisols derived from serpentine in western Cuba and as a lesser component with *P. tropicalis* Morelet on soils derived from shales and sandstones *(84)*. Pure pine stands on the Belize coastal plain have understories dominated by bracken, *Pteridium* spp., and dumb cane, *Tripsacum* sp. *(64)*.

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Narrow, cylindric, red-brown male catkins about 2.5 cm long are borne on lower side branches. They fall soon after the pollen is shed. The species is monoecious (male and female flowers on the same tree). The female cones are borne in groups of one to five near the ends of erect twigs in the upper part of the crown. Female cones are less than 1.3 cm long at pollination, about 1.9 cm long at the end of the second year, and 5 to 12 cm long at maturity *(54, 75)*. The time lapse between pollination and ripening of cones averages between 18 and 21 months *(10)*. In any one locality, all the cones ripen at about the same-time, regardless of the time of pollination. The peak period of ripening is May or June in Nicaragua, July in Belize and Honduras, June and July in Cuba, August in the Bahamas, and September in Puerto Rico *(10, 54)*.

Seed Production and Dissemination.—Caribbean pine seeds are brown, 5 to 6 mm long, with a 20-mm wing attached *(75)*. Seed weight varies somewhat by variety and source. Counts of 52,000 to 81,000 seeds per kilogram are reported *(10)*. Production of viable seeds of Caribbean pine (Central American sources) are related to dry periods, which favor good pollen dispersal *(51)*.

Plantations begin producing cones (female flowers) when 4 years old in Trinidad and Tobago *(85)*. Cones on trees start to release seeds 2 to 3 weeks after the cones turn brown, depending on weather conditions *(10)*. Collection of cones can begin when the cones start to turn from green to brown. Harvested green cones may be artificially dried at temperatures of between 30 and 60 °C to extract seeds. Viability is about equal to that obtained with the traditional sun-drying method. A small increase in germination is reported from storing green cones at 5 °C for 13 days before drying *(74)*.

Seedling Development.—Germination begins in an average of 12 days after sowing in the nursery bed *(60)*. Germination may vary from nearly 100 percent to very low percentages, depending on the condition of the seeds. Low-vigor Caribbean pine seeds capable of only 5-percent germination with the seedcoat removed demonstrate a 25-percent germination when treated with a 5-milimole solution of gibberellic acid *(91)*.

Direct seeding of Caribbean pine has been successfully demonstrated in Honduras. Seed treatments with insecticides and repellents are a must for satisfactory germination in the field *(88)*. Prepared seed spots generally give better results than broadcasting.

Caribbean pine is widely planted as containerized stock. Several types of containers have been used successfully. Currently, the most popular type is the plastic nursery bag. It allows a large seedling to be produced but has the disadvantage of considerable weight and bulk to transport and root systems that often have poor form. Seeds can be sown directly into nursery containers. Because of uncertain germination, seeds are generally germinated in trays and the seedlings pricked into containers a few days after emergence. An average mortality of 12 percent is reportedly associated with this operation *(94)*. Sandy soil without amendments is a better potting medium than forest soil or mixtures of sand and manure *(59)*.

A more practical but higher risk method is planting bare-root seedlings. Survival of bare-root seedlings is strongly related to planting stock quality, a result of nursery bed fertility and stocking density. The percentage of cull seedlings rises rapidly above a density of 156 plants per square meter *(82)*. Frequent root wrenching (undercutting) of bare-root seedlings in Honduras produces smaller seedlings with a better root/shoot ratio and better survival when outplanted than seedlings not wrenched *(69)*. Dipping the roots in a clay slurry has been beneficial in Australia *(82)*.

Bare-root seedlings in Honduras are produced in about 5 to 6 months in the nursery. By this time they are 15 to 25 cm high and have a root collar diameter of 3.0 mm or greater *(11)*. Best growth of outplanted seedlings has been associated with seedlings ranging from 16 to 32 cm in height and having root collar diameters of more than 4.5 mm *(23)*.

Bare-root seedlings can be safely stored when sealed (whole plant) in plastic bags at 3 to 9 °C for 1 month without important loss in viability. Longer storage results in higher mortality, but seedlings sealed in heavy plastic and stored for 7 months at 3 to 4 °C still demonstrate a survival of 64 percent compared to 80 percent for freshly lifted controls *(25)*.

Because of lower cost, trials and some operational plantings are being done with bare-root stock. In one test in Cuba, field survivals (21 months) of 75 to 91 percent were recorded, depending on nursery treatment *(2)*. Bare-root stock planted in Tanzania had considerably lower survival (48 vs. 79 to 98 percent) than balled or tubed seedlings but did not have a significantly slower growth rate *(100)*. Planting into a subsoiled slit resulted in a deeper, more branched root system than planting into an ordinary planting hole *(43)*.

Postplanting weed control is often required to avoid suppression and high mortality of seedlings *(58)*. Some plantations, especially on abandoned farm land, require little or no weeding; more fertile sites require much greater care. Caribbean pine plantings in fertile Puerto Rican sites were not adequately protected by five cleanings with machetes and two herbicide treatments over a 17-month period *(34)*.

Vegetative Reproduction.—Caribbean pine is routinely grafted during tree breeding operations. Field grafting in a top cleft position typically yields 60 to 100 percent successful unions *(83)*. Air-layering has also been successfully used to propagate this species *(10)*.

Sapling and Pole Stage to Maturity

Growth and Yield.—Height growth in the first 20 years or so ranges from about 0.75 to 1.5 m/yr (table 1). Height growth slows after 15 to 25 years, and a maximum height of 30 to 40 m on good sites is eventually reached. Maximum diameters at breast height (d.b.h.'s) of 0.5 to 1.5 m may be expected, depending on site quality.

Current annual volume increments in cutover natural stands in Nicaragua vary from about 2 to 8 m^3/ha/yr. Unmanaged natural stands in Honduras, situated on soils too poor for agriculture, currently produce 2.5 to 3.0 m^3/ha/yr. With good management, yields of 6 to 11 m^3/ha/yr can be expected *(29)*. The increments in similar stands in Cuba and

Table 1.—*Growth information for Caribbean pine* (Pinus caribaea) *plantations in diverse localities*

Location	Variety*	Age	Precipitation	Mean d.b.h.	Mean height	Source
		Years	*mm/yr*	*cm*	*m*	
Turrialba, Costa Rica	h	2.0	2673	5.2	3.6	*(79)*
Assis, Brazil	h	3.2	...	...	7.2†	*(37)*
Buhindi, Tanzania	h	3.2	...	...	5.2	*(37)*
Viñales, Cuba	c	4.8	1765	...	4.1	*(3)*
Viñales, Cuba	b	4.8	1765	...	2.8	*(3)*
Frankfort, South Africa	h	5.0	...	14.0	11.3	*(85)*
Verata, Fiji	h	5.4	2150	14.2	9.6	*(73)*
Drasa, Fiji	h	5.8	2150	11.4	7.9	*(73)*
Afaka, Nigeria	h	9.0	1290	...	12.0	*(4)*
Uplands, Puerto Rico	h	10.0	2000	19.0	13.6	*(33)*
Curua, Brazil	h	12.0	...	...	17.0†	*(50)*
La Yeguada, Panamá	h	12.0	3463	17.6	15.6	*(35)*
San Lorenzo, Puerto Rico	h	12.0	2340	21.3	14.4	*(47)*
Drasa, Fiji	h	12.5	2132	21.6	18.5	*(16)*
Nassori Highland, Fiji	h	12.5	2578	27.9	20.3	*(16)*
Kuranta 212/1, Australia	h	15.0	1130	...	15.8	*(5)*
Kuranta 212/2, Australia	h	15.0	1130	...	21.6	*(5)*
Costa Rica	h	17.0	...	25.8	25.6	*(71)*
Wongable, Australia	h	17.0	1427	...	26.0	*(5)*
Gadgarra, Australia	h	17.0	2000	...	30.8	*(5)*
Lares, Puerto Rico	h	18.0	2000	...	30.0‡	*(53)*
Moca, Puerto Rico	h	19.0	2320	24.3	25.3	*(47)*
Blue Mountains, Jamaica	h	20.0	2000	32.3	27.0‡	*(50)*
Utuado, Puerto Rico	h	22.0	1740	25.8	25.3	*(47)*
Luquillo, Puerto Rico	b	23.0	3000	25.5	19.6	*(30)*
Luquillo, Puerto Rico	h	24.0	3000	45.5	25.6	*(30)*
Luquillo, Puerto Rico	c	26.0	3000	29.3	21.6	*(30)*
Dukuduku, South Africa	h	27.0	...	40.4	23.5	*(85)*
Lacetilla, Honduras	h	32.0	3280	36.0	23.7	*(41)*

*h=*P. caribaea* var. *hondurensis,* b=*P. caribaea* var. *bahamensis,* c=*P. caribaea* var. *caribaea*

†In studies where multiple provenances or sites are compared, data on the best provenance or site are given.

‡Height of dominant trees only.

the Bahamas may be as low as 1.4 m^3/ha/yr *(10)*. Most of the natural stands are composed of older trees that have gone through many years of suppression and slow growth. Plantations generally have a yield advantage over existing natural stands because of younger ages, full stocking, and generally better sites. Plantation yields (total bole volume, outside bark) above 15 m^3/ha/yr can usually be expected on suitable sites. Projected yields for plantations at 15 years on "best" sites, based on many trials, were 35, 27, 32, 24, and 32 m^3/ha/yr for Costa Rica, Jamaica, Puerto Rico, Trinidad and Tobago, and Venezuela, respectively *(52)* Much higher yields (up to 52 m^3/ha/yr) have been reported on small plots (table 2). Yield tables have been prepared that give yields at various ages, growth rates (site classes), and stockings *(49)*. Also, models have been developed for predicting yield in terms of weight of stemwood biomass produced *(56)*.

Because of overcutting and frequent fires, basal areas of Caribbean pine in its natural range tend to be very low, often 5 m^2/ha or less. (A basal area of 25 m^2/ha is considered average for fully stocked, mature natural pine stands in Honduras *(29)*.)

Growth curves for different site classes (site index curves) have been constructed for trees in plantations in Surinam *(93)*, Trinidad and Tobago *(49)*, Mexico *(28)*, and Puerto Rico *(47)*. No convention has yet been established for site index age; however, 20 or 25 years old seems to be most appropriate for this age. Volume models and tables estimating inside and outside bark volumes to given top diameters have been developed for plantation-grown trees in several locations (table 3). A table has been published *(50)* giving the proportion of wood volume of total bole volume of various-size Caribbean pine trees in Uganda. Wood varied

Table 2.—*Exceptional volume increments from Caribbean pine plantations in various parts of the world*

Location	Age	Total volume	Mean annual volume increment, including bark	Source
	Years	*m^3/ha*	*m^3/ha/yr*	
Jari, Brazil	6.0	182*	30.3*	*(97)*
Afaka, Nigeria	9.0	135	15.0	*(4)*
Curua, Brazil	12.0	317*	26.4*	*(50)*
La Yeguada, Panamá	12.0	292	24.3	*(35)*
Puerto Rico (composite 7 plots)	12.0	263*	21.9*	*(47)*
Guzman, Puerto Rico	12.3	646	52.5	*(96)*
Utuado, Puerto Rico	12.5	580	46.4	*(96)*
Lares, Puerto Rico	18.0	867	48.2	*(53)*
Puerto Rico (composite 6 plots)	19.0	351*	18.4*	*(47)*
Caracoles, Puerto Rico.	20.0	782	39.1	*(53)*
Toolara, Australia	21.0	450	21.4	*(6)*
Trinidad, Trinidad and Tobago	25.0	501*	20.0*	*(65)*

*Volume and volume increment inside bark (49 to 68 percent of volume, outside bark).

Table 3.—*Volume models and tables developed for Caribbean pine* (Pinus caribaea) *in various parts of the world*

Area where developed*	Volumes predicted within these limits†	Source
Australia	OB to 5 top diameters; models only	*(90)*
Cuba	IB and OB to 1 top diameter; 6 to 28 cm in d.b.h.	*(17)*
Cuba	IB and OB to 2 top diameters; 6 to 30 cm in d.b.h.	*(68)*
Dominican Republic	OB to 1 top diameter; 4 to 50 cm in d.b.h.	*(78)*
Guatemala	IB and OB to 4 top diameters; 26 to 80 cm in d.b.h.	*(76)*
Jamaica	IB (limits not stated)	*(48)*
Jamaica	OB to 1 top diameter; 13 to 51 cm in d.b.h.	*(50)*
Malaya	IB and OB to 1 top diameter; 8 to 28 cm in d.b.h.	*(80)*
Panamá	IB and OB to 3 top diameters; 9 to 35 cm in d.b.h.	*(89)*
Puerto Rico	IB to 1 top diameter; 10 to 46 cm in d.b.h.	*(47)*
Surinam	IB and OB to 4 top diameters; 4 to 42 cm in d.b.h.	*(92)*
Tanzania	IB and OB to 4 top diameters; 6 to 50 cm in d.b.h.	*(1)*
Tanzania	OB to 1 top diameter; 5 to 50 cm in d.b.h.	*(13)*
Uganda	OB to 1 top diameter; 10 to 32 cm in d.b.h.	*(50)*

*Except for the Cuban sources (*P. caribaea* var. *caribaea*), all were developed for *P. caribaea* var. *hondurensis*.

†IB=inside bark, OB=outside bark, d.b.h.=diameter at breast height.

from 49 percent of the total in 10-cm-d.b.h., 4-m-tall trees to 68 percent of the total in 32-cm, 20-m trees. Bark thickness of plantation trees in Trinidad averaged 1.2, 1.7, 2.1, and 2.3 cm for trees in the d.b.h. classes of 0 to 10, 11 to 20, 21 to 30, and 31 to 40 cm, respectively *(49)*.

Age of Caribbean pine trees can be approximated by counting the highly distinct rings. In one Cuban study, the ring count matched the age of the plantation *(67)*. However, in another Cuban study, the age coefficient (actual age/number of rings) for Caribbean pine was 0.8 *(36)*.

Rooting Habit.—Seedlings rapidly produce a taproot with many laterals. The form of the adult root system is largely controlled by the environment. Deep root systems with long taproots are produced in deep, sandy soils, and shallow, lateral root systems are produced in clay soils having poorly aerated subsoils. Evidently, root grafting is a common occurrence. Stumps in Puerto Rico often stay alive for several years and form a callus over the cut. These stumps are apparently supplied with nutrients through their root attachments with nearby trees (author, personal observation).

The roots of pines are normally associated with ectomycorrhizal fungi. Mycorrhizal fungi increase the absorption of water and nutrients in a tree and may offer some protection from root pathogens. Although pine seedlings can grow normally in constantly fertilized medium without mycorrhizal fungi, survival in natural soils is impossible without the symbiont. Many attempts to establish pines in Puerto Rico, which has no native pines, were unsuccessful until inoculated seedlings and inoculum were imported from pine-growing areas *(14)*. Artificially inoculating Caribbean pine seedlings with *Pisolithus arrhizus* resulted in 31 percent more seedling height at 11 months old than seedlings inoculated with pine forest floor material containing the fungi *Telephora terrestris (27)*. The symbiotic fungi *Pisolithus tinctorius* (Pers.) Coker & Couch. has been identified in association with Caribbean pines in Brazil, Puerto Rico, Australia, and Mexico *(63)*.

Reaction to Competition.—At 18 to 20 years old, the best plots in a Puerto Rican unthinned spacing study had above 70 percent survival. The three narrowest spacings (1.5 by 1.5 m, 2.1 by 2.1 m, and 3 by 3 m) yielded the greatest total bole volume but produced smaller diameters than wider spacings *(53)*. As with most species, tree density or basal area strongly influences the rate of diameter growth of the individual trees in the stand. Basal areas of 20 to 60 m^2/ha are common in plantations, and basal areas as high as 90 m^2/ha have been reported *(47)*. Little mortality occurs until a basal area of 70 m^2/ha is reached. Thinnings to straddle a basal area of 34 m^2/ha are suggested to maintain rapid diameter growth *(8)*. For pulpwood production on a 10-year rotation, management for an initial stand of 800 to 900 trees per hectare is recommended. For a combination of pulpwood and sawlogs, heavy thinning at 6 to 8 years is recommended. For purely sawlog production, densities of from 200 to 700 trees per hectare should be established, depending on the minimum tree diameter accepted *(19)*. Precommercial thinning results in more total volume produced and greater economic return in a sawlog rotation than repeated commercial thinnings *(8)*.

Damaging Agents.—The pine bark beetles *Dendroctonus frontalis* Zimmerman and *D. mexicanus* Hopk. are serious pests of Caribbean pine in Central America *(10)*. They are endemic as secondary parasites and also frequently attack healthy trees. Slightly less destructive in healthy stands are *Ips calligraphus* Germar and *I. avulsus* Eich in Central America and the Caribbean. Large outbreaks are triggered by stress associated with hurricane damage, drought, fire, or excessively dense pine stands. Other less widespread damage may result from attacks by aphids (Adelgidae and Aphididae), weevils (Curculionidae), buprestid beetles (Buprestidae), spider mites (Tetranychidae), leaf cutter ants (*Atta* spp., Formicidae), termites (Isoptera), and moths (Lepidoptera) *(10)*.

Caribbean pine wood is not susceptible to attack by powderpost beetles (*Lyctus* spp.) *(18)*. Resistance of the wood to dry-wood termites (*Cryptotermes brevis* Walker) is related to the resin content. Resin-soaked heartwood is very resistant, whereas wood with a low resin content is only moderately resistant *(55)*. Caribbean pine wood has little resistance to marine borers (*Toreda* spp.).

New nursery seedlings of Caribbean pine are moderately susceptible to "damping-off" disease. The disease is caused by the fungi *Thanatephorus cucumeris* (Frank) Donk., *Rhizoctonia solanti* (Kuhn), *Pithium* spp., and *Fusarium* spp. The incidence of "damping-off" can be reduced by avoiding too much raw organic matter, excessive moisture, high pH or alkalinity, and high sowing density *(10)*. Losses of trees to the root pathogenic fungi *Armillaria mellea* (Vahl) Kummer, *Phytophthora cinnamomi* Rands., *Fomes annosus* (Fr.) Cooke, and *Gylindrocladium* spp. are reported in plantations around the world *(12, 15, 44, 87)*.

In a test of eight tree species that were cut into railroad ties and stored in the open in Cuba, wood of Caribbean pine was the most susceptible to rot. The fungi *Schizophyllum commune* Fr., *Coriolopsis fulvocinerea* Murr., *Dacryopinax spathularia* (Schw.) Martin, *Auricularia* sp., and *Coriolopsis occidentalis* (Klotzsch.) Murr. were detected in the test pieces *(38)*.

SPECIAL USES

Wood Quality

Caribbean pine sapwood is light yellow contrasting to the golden-brown to red-brown heartwood. The rings are distinct and sharply demarcated. False rings may also be present (personal communication, Clark Lantz, Cooperative Forestry, USDA Forest Service, Atlanta, GA). Wood texture is medium to somewhat coarse, and the grain is straight. The wood has a medium luster, and compression wood is frequently present.

Density is a critical determinant of wood quality. Caribbean pine density varies with the proportion of sapwood and heartwood, the quantity of juvenile wood at the core, and the percentage of resin deposited in the wood. The density of Caribbean pine wood ranges from below 0.3 g/cm^3 to over 1.0 g/cm^3 in resin-soaked material *(77)*. Wood densities in commercial lumber commonly range from 0.4 to 0.7 g/cm^3. In nonresin-soaked wood, growth rate is apparently the strongest determinant of wood density. The faster growing *hondurensis* variety tends to have a slightly lower density than the *caribaea* and *bahamensis* varieties *(77)*. Wood densities of fast-growing plantation trees in Brazil range from

0.35 to 0.41 g/cm^3 *(98)*. Provenance, site, and the genetic differences between one tree and another can have a considerable effect on wood density *(9, 46, 70)*.

Naturally grown Caribbean pine lumber with a moisture content of 12 percent had a bending strength of 1173 kg/cm^2, a modulus of elasticity of 157,000 kg/cm^2, and a maximum crushing strength of 600 kg/cm^2 *(95)*. These figures are comparable to values for slash pine (*P. elliottii* Engelm.). Testing of low-density, plantation-grown wood should result in considerably lower values.

Low-density plantation wood seasons rapidly without much loss of grade, but denser material air-dries slowly, with a tendency to end-split in thick stock. Shrinkage from green to ovendry is 6.3 percent radial, 7.8 percent tangential, and 12.9 percent volumetric *(21)*.

Utilization

Few difficulties are encountered during machining of Caribbean pine wood except for resin-soaked wood, which can clog and gum-up cutting edges and sliding surfaces *(77)*. Greater uniformity within annual rings and fewer knots result in greater ease of working with this species than with many temperate conifers such as *P. elliottii (77, 81)*.

There are a great many uses for Caribbean pine wood. Lumber is the greatest single use; however, because of the high variability in strength, the lumber should only be used in construction of low-stress products such as sheathing, partitions, sills, flooring, and decking *(77)*. Pallets, boxes, treated posts, poles, inexpensive furniture, and toys are other uses. Because of its durability, resin-soaked wood is still popular for boat decking. The wood is reportedly suitable for plywood, woodwool-cement board, and particleboard *(20, 40, 77, 99)*.

Chips from Caribbean pine are suitable for various types of pulp, except for dissolving-grade pulp *(77)*. Chips for pulp are produced from the species in Brazil, Australia, Central America, and Africa.

Caribbean pine wood is used to a limited extent for firewood, kindling, making charcoal, and serving as torches. The gross caloric value (dry basis) of Caribbean pine wood is given as 20,298 kJ/kg *(39)*. The value would vary considerably according to the resin content of the wood sampled. The species is tapped for resin in Central America *(75)*. Tannin extracted from Caribbean pine bark is suitable for tanning leather. Tannin yields of 5 to 10 percent of the ground bark are obtained, depending on extraction method, tree age, and variety of the species *(61, 62)*. The bark of 15-year-old trees in various countries around the Caribbean Basin ranged from 13 to 21 percent of the volume at d.b.h. *(52)*.

Nonwood Benefits

Caribbean pine is used as an ornamental and shade tree, partly due to its fast growth and hardiness on most soil types, including partially compacted fill. The constant dropping of needles is considered a nuisance by some people. The species is also extensively planted to stabilize and restore eroded and nutrient-depleted sites. It is particularly good for protecting disturbed watersheds.

A Caribbean pine plantation was compared with a broadleaf secondary forest of similar age in Puerto Rico *(22)*. The two types produced similar quantities of total organic matter. The pine plantation generated more litter and fewer fine roots than the broadleaf secondary forest. Numbers of plant species increased under trees in Caribbean pine plantations to almost the level existing in secondary broadleaf forests having dominant trees of similar age *(57)*.

GENETICS

Three varieties of Caribbean pine are recognized by taxonomists: *P. caribaea* var. *caribaea* from Cuba and the Isle of Pines, *P. caribaea* var. *hondurensis* from Central America, and *P. caribaea* var. *bahamensis* from the Bahamas and Caicos Islands. These varieties differ somewhat from one another in number of needles per fascicle, cone size, and seed wing anatomy *(10)*. Significant differences exist within provenances of at least the Central American variety in extractive-free wood density *(46)*. This and all other pine species have 2n=24 chromosomes *(66)*.

Progeny tests from selected seed orchards in Queensland, Australia, showed considerable improvement in form. On the average, progeny of selected material (Mountain Pine Ridge, Belize source) produced 3.5 times more straight logs above 6 m than trees grown from nonselected seeds from Poptun, Guatemala. Branch diameter and angle were not affected, multiple leaders decreased slightly, and resistance to wind damage decreased in progeny of the Belize material *(26)*. A mean heritability of 67 percent for resin yield is reported in Cuba *(7)*. Narrow-sense heritabilities for 26 open-pollinated families in an 11-year-old progeny trial in Australia gave h^2=0.55 for wood density and h^2=0.54 for percentage of latewood. Ring width (h^2=0.23) and compression wood (h^2=0.10) displayed relatively little genetic control *(25)*.

Natural hybrids occur between *P. caribaea* var. *hondurensis* and *P. oocarpa* Schiede and *P. oocarpa* var. *ochoterenai* where the ranges overlap in Central America. The hybrids are reported to have better form and faster growth than either parent species *(75, 86)*. Artificial hybrids with *P. elliottii*., *P. patula* Schl. & Cham., and *P. oocarpa* have been produced. First generation hybrids (F1) of *P. caribaea* var. *hondurensis* and *P. elliottii* exceed the latter parent in growth in southern Queensland and are recommended for planting in swampy sites. The F2 hybrid, which is considerably cheaper to produce, grows slower than the F1 hybrid but still faster than *P. elliottii (25)*. The *P. caribaea* X *patula* hybrid was reported to have exceeded the faster growing parent (Caribbean pine) in height at 5.5 years old. Survival was excellent, and wood density was acceptable *(24, 25)*.

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